

Radio variability of 1st 3-months *Fermi* blazars at 5 GHz: affected by interstellar scintillation?

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Abstract. Blazars from the first-three-months *Fermi*-AGN list were observed with the Urumqi 25 m radio telescope at 5 GHz in IDV (Intra-Day Variability) mode and inter-month observation mode. A significant correlation between the flux density at 5 GHz and the γ -ray intensity for the *Fermi*-LAT detected blazars is seen. There is a higher IDV detection rate in *Fermi* detected blazars than those reported for other samples. Stronger variability appears at lower Galactic latitudes; IDV appears to be stronger in weaker sources, indicating that the variability is affected by interstellar scintillation.

Key words: active galactic nuclei: blazars – radio continuum: variability – γ -ray: *Fermi*-LAT

1. Introduction

In the 1990s the space γ -ray telescope EGRET identified 66 blazars. *Fermi*, launched in 2008, has a much higher sensitivity and pointing accuracy than EGRET. After first three months of observations with the *Fermi*-LAT (Large Area Telescope) 132 bright γ -ray sources are detected, of which 104 are blazars (Abdo et al. 2009).

Blazars are either flat-spectrum radio quasars or BL Lacertae objects, and they are extremely variable at all wavelengths on timescales ranging from less than an hour to many years. Such violent behavior in blazars is attributed to relativistic jets oriented very close to our line of sight (Urry & Padovani 1995).

Intra-Day Variability (IDV, fast variability on time scales from a few hours to few days) of the radio flux density has been found in about 30–50%

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of all flat-spectrum radio sources (Quirrenbach et al. 1992; Lovell et al. 2007). If interpreted as being source intrinsic, the rapid variability would imply micro-arcsecond scale sizes of the emitting regions. Alternatively, IDV can be caused by interstellar scintillation (ISS), especially for very rapid variability seen in some sources, e.g. Gabanyi et al. (2007).

Since most of the *Fermi*-LAT detected AGN are blazars, it is expected that γ -ray emitting AGN are more variable than non γ -ray emitting AGN. Therefore we launched in March 2009 a 5 GHz monitoring program with the Urumqi 25 m radio telescope, to observe the intra-day variability and the inter-month variability of first three-months detected *Fermi* blazars with declination $>0^\circ$. We aim to enlarge the number of known IDV sources and to study the statistical occurrence of (rapid) variability in *Fermi* blazars.

2. Observations and data reduction

The IDV observations were carried out from March to May 2009 with a duration of 4-6 days per session. The sources were observed typically every 3 hours using the ‘cross-scan’ method. Sources which were not point-like for the Urumqi beam or were confused (non Gaussian brightness profiles) were rejected from our sample. Finally, we link our observations to the absolute flux density scale of Ott et al. (1994). From the variability light curves from each source, we obtain the modulation index (m), and the mean flux density ($\langle S \rangle$).

Following Kraus et al. (2003), m is defined by the ratio of the standard deviation of the flux density and the mean flux density of source. It provides a reliable measure of the strength of the observed amplitude variations:

$$m[\%] = 100 \frac{\sigma_S}{\langle S \rangle}$$

The modulation index m_0 observed for the calibrator sources provide a measure for the residual calibration errors, which are around 0.5 [%].

The inter-month observations were carried out from March to December 2009, with one flux density measurement per month for most sources. We define the modulation index M for the inter-month flux density variations similar as m for the IDV. For the calibrators we obtain $M_0 \sim 2$ [%]. Finally, 42 blazars are observed in the IDV and inter-month observations; 11 blazars are not included in the IDV and inter-month observations, most of them are relatively weak with flux densities measured in March 2009.

3. Results and discussion

A significant correlation between the flux density at 5 GHz and γ -ray intensity in the *Fermi*-LAT blazars has been found and is shown in Fig.1 left, with Pearson correlation coefficient of 0.42 in total, and 0.40 for QSOs and 0.59

for BL Lacs. Following a χ^2 -test for variability, we find 26 sources (16 QSOs and 10 BL Lacs) showing intra-day variability at a confidence level of larger than 99.9%, from 42 sources. The IDV detection rate of 62 % in the *Fermi* blazar sample is higher than those reported in previous flat-spectrum AGN samples. This could be caused by a higher compactness of *Fermi* blazars relative to sources in other samples.

The majority of the sources also show inter-month variability, no obvious correlation was found between the intra-day and inter-month variability. For the still very short time coverage of the inter-month data, one may need a much longer time coverage for a better characterisation of the inter-month variability. The median values of the variability strength for m or M are quite similar for quasars and BL Lacs. Pronounced inter-month variability ($\sim 40\%$) was found in two BL Lac objects: B 0109+224 and B 0235+164. There is only a weak or marginal correlation between the source spectral index and either the intra-day or inter-month variability index, since all sources exhibit similar flat spectra.

On the other hand, in our sample stronger intra-day variability (m) appears in weaker sources as shown in Fig. 1, right. This could be explained by ISS as suggested by Lovell et al. (2007). Another interpretation of this phenomenon is that the weak ones might show less powerful and less pronounced jets. From VLBI we know that the IDV comes from the core region, so a 'naked' core might show a higher variability index than a source which shows a long and prominent jet. It is well possible that faint sources show less jet emission, which means that they are more core-dominated. This would automatically lead to more pronounced IDV. Our data show stronger inter-month variability (larger M) at lower Galactic latitude except for two outliers B 0109+224 and B 0235+164, as shown in Fig. 2 left. This also points towards interstellar scintillation similar to the effect previously found by Rickett et al. (2006) in data from the Green Bank Interferometer. However, we should check if the sky coverage of our sample is sufficiently uniform. Fig. 2 right reveals some deficiency of our sample at $50^\circ - 80^\circ$ latitude. A future extension of the size of the source sample and a longer time coverage for the long-term variability should help to discriminate between propagation induced effects (ISS) and source intrinsic properties. Following the pilot study presented in this paper, we now have launched a program 'Search for rapid variability in a large sample of radio sources with the Urumqi telescope' in 2010. As parent sample, we use the CRATES (Healey et al. 2007) catalogue to study the variability statistics in more detail.

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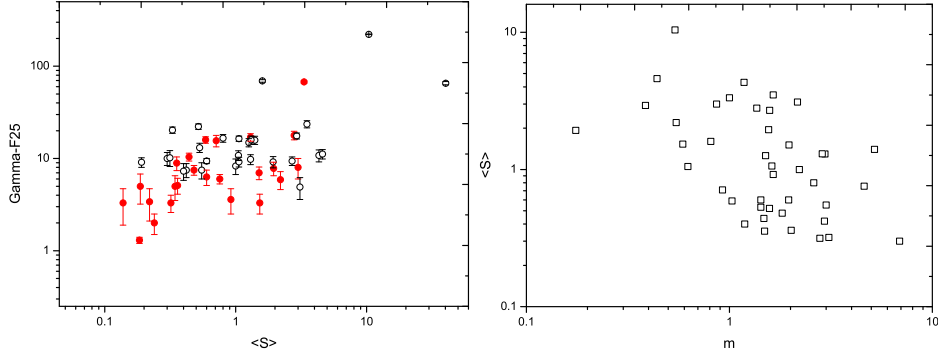


Figure 1. Left: The γ -ray intensities (with error) (≥ 100 MeV, in units of $10^{-8} \text{ ph cm}^{-2} \text{ s}^{-1}$) for 53 *Fermi* detected blazars plotted versus the flux densities (Jy) at 5 GHz, filled: for BL Lacs, circles: for QSOs. Right: The mean flux densities (Jy) plotted versus the modulation indices of 42 *Fermi* detected blazars from our IDV observations.

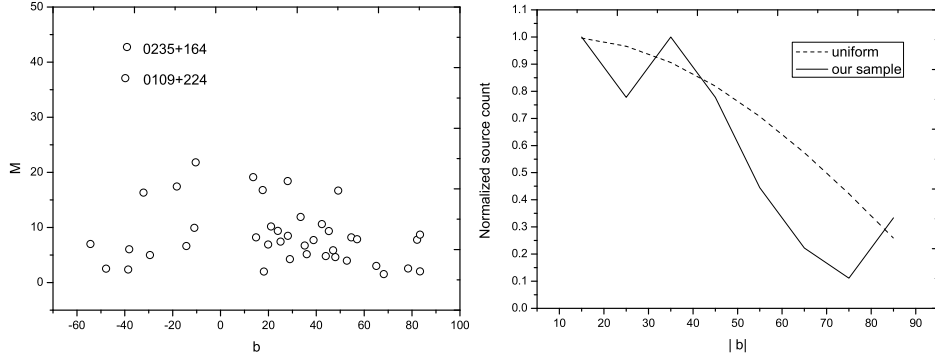


Figure 2. Left: The modulation index of inter-month variability versus Galactic latitude of the source. Right: Normalized source count of our sample (solid line) and that for a uniform sky distribution (dashed line) versus Galactic latitude $|b|$.

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